

**DRAFT EXECUTIVE SUMMARY  
SUGAR PLATFORM COLLOQUIES**

by

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## EXECUTIVE SUMMARY

Four colloquies were held in late 2001 for discussing what is needed to accelerate lignocellulosic biomass based products from sugar fermentations to commercialization and how the Department of Energy, DOE, the National Renewable Energy Laboratory, NREL, and other government actions can help.

Each session brought together participants with a general knowledge of the issues but different individual expertise--a multidisciplinary group that were in a position to influence the future direction of the industry. They represented the following industry segments:

- Chemical Companies
- Enzyme Producers
- Corn Wet Millers
- Microbe Developers
- Potential Biomass Suppliers
- Life Science Companies
- Petroleum Industry

The topics discussed in the colloquies are below:

- Feedstock Availability, Collection and Storage
- Economic Process
- Process Validation
- Commercialization timeline
- Market Outlook
- Environmental Factors
- Government Actions

Major topic findings were related to feedstock, sustainability and the need for the initial commercialization to have industry leadership:

**Feedstock:** Plants will locate near low-cost, reliable and abundant feedstock like crop residues, particularly corn stover. Improved harvest and storage methods will increase supply reliability, return more than \$20/acre income to farmer and reduce delivered cost from \$35/dry ton delivered to \$25 or less.

**Sustainability:** The sustainability profile for feedstock production and harvest needs to be researched and balanced with alternative applications—e.g., fuel and dispersants. Improved awareness of the environmental impact is needed.

**Industry Leadership:** Biomass hydrolysis development and demonstration requires industry leadership. Companies from the chemical industry are strong prospects for leadership roles because of their R&D spending, technical capabilities and need for sustainable processes.

**Initial Commercialization:** Industry will likely form partnerships to develop proprietary technology for first plants. A consortium is less likely. Key government actions to accelerate the commercialization effort Include:

- Support process development and demonstration as a resource provider, assisting industry partners to become the technology supplier
- Recognize the development and demonstration of an economic biomass hydrolysis process will likely cost \$50 million or more in capital and research expense and scale solicitations that recognize this cost
- Set the goals to be accomplished and solicit for industry cost shared proposals to reach them

## 1. FEEDSTOCK

Corn stover and other crop residues are the most likely feedstocks. Considerable sugar cane could be available if the process economics are demonstrated. Switchgrass may emerge as more sustainable in the long term when the yield is improved without “inputs” required for cash crops.

There appear to be no “show-stoppers” for obtaining corn stover and straw throughout the year in a win-win manner for both farmer and processor. A price in the \$35 to \$40/dry ton delivered within a 50 mile radius. One-pass harvest and bagasse type storage is likely to reduce this to below \$25 while still returning \$20/acre income or more to the farmer.

Unresolved issues revolve around sustainable harvest. Extending the present knowledge to better define the removal impact is needed that account for anticipated changes in the crop management and harvest practices.

Plant science offers significant opportunities to improve yield a lower cost that are most likely to be realized in the mid to long term, 5 to 10 years in the future.

## 2. ECONOMIC PROCESS

Development of an economic process is a major concern, more than feedstock cost and availability. Industrial partners are needed to set the development direction. Pretreatment is the most critical unit operation. A multiple disciplinary approach that couples biotechnology and chemistry with process engineering will achieve best design and cost.

Pretreatment and enzyme hydrolysis development needs to be linked now. Unless the substrate from the pretreatment closely matches that from the full scale pretreatment scheme, the enzymes developed may not achieve the same performance in a commercial plant.

A small, integrated corn stover feedstock process must be operated to better determine the following:

- feedstock variation effect
- pretreatment condition limits
- assess enzyme hydrolysis
- fermentation microbe performance
- improve cost estimate
- fix design for next plant scale

A pilot plant between a kilogram and one ton per day needs to operate continuously for design confidence: closing carbon and other material balances, establishing process yields and stream composition, testing materials of construction, yields and providing more fundamental and macro knowledge.

### 3. PROCESS VALIDATION

Following the small scale demonstration, an intermediate scale plant is needed to reduce risk for potential investors and other stakeholders: employees, feedstock suppliers and customers associated with building the “first-of-a-kind” commercial plant costing about \$200 million.

Process guarantees provided by the design engineering companies are not an adequate substitute. The guarantees are expensive and have not helped their holders to access capital for biomass plant projects that have skipped the intermediate scale process validation step

A continuous operation on a “semi-commercial” scale demonstrates the design basis and better insures that the larger process design will produce a quality product that meets the customer requirements safely, within budget, and complies with all environmental requirements.

The scale-up using stover and other crop residues is likely to be 20 to 50 X for the pretreatment step and 1,000 or more for fermentation. The estimated cost is \$40 to \$50 million when co-located on an existing site. Products from the plant are not expected to cover the operating cost.

Wet millers may be able validate corn fiber conversion for less cost. Since the composition and physical properties of the fiber are significantly different from crop residues, using this route as a prologue to residues is not likely.

Industrial participation can take several forms including consortiums, partnering and leasing. A consortium was too expensive and complex to function and meet most potential member's needs. Participants already working in the area preferred partnering with others that leverage their expertise. Funding the construction of a large government facility, similar to the 40 dt/day logen plant and leasing it to others was not considered plausible.

### 4. COMMERCIALIZATION TIMELINE

There are multiple biomass commercialization plans underway. NREL's schedule matches up with the improved enzymes expected to be available in 2003 and 2004 from Genencor and Novozymes. Others have similar plans for a

commercial plant in the next 3 to 5 years. Iogen has announced plans to have a commercial ethanol plant underway by 2004-2005.

NREL indicated they would hold a meeting to discuss the timeline and related issues in January, 2002. All the colloquy participants will be invited to attend, along with others that have interest.

## 5. MARKET OUTLOOK

Fuel ethanol and chemicals are the target markets. The fuel ethanol market is subsidized, at least until 2007. Chemicals are not. Both require additional government support to become a commercial reality in the above timeframe.

Participants said the price—8¢ to 9¢/lb—for fermentation sugars from corn and other grains limits commercialization. Advances in biotechnology have resulted in process routes that were previously impossible. The processes become economic at 3¢ to 5¢/lb without government support. Many of the products now produced from petroleum feedstocks could be moved to a biobased process.

The huge scale for these makes the market for by-products difficult to develop and manage. By-product quantities can easily exceed their market needs. As a result, most expected much of the lignin would be used as a boiler fuel.

## 6. ENVIRONMENT

The chemical industry is pursuing sustainable development as an integral extension of their business. In terms of the “triple bottom line,” projects must stand on the financial returns while meeting corporate environmental and social objectives and goals. “Natural capital” and “social capital” are more difficult to appraise. Natural capital is measured in environmental terms. Social capital measures are more qualitative.

Cleaner technologies like biotechnology are being emphasized—e.g., placing biotechnologists with traditional process design people to create new technology platforms. The effort is likely to speed up as greenhouse gas emission rules are implemented.

## 7. CONCLUSIONS

The program to commercialize biomass to ethanol is largely on track. Plans to reduce feedstock costs by nearly 50% are in place. Enzyme and ethanologen development continue as planned. The two largest issues remaining are:

- Integrating the process development
- Attracting industrial participants to co-fund the validation stage

More integrated development is needed before risking a \$200 million investment in the first plant. This development needs industry direction and participation. To overcome these barriers, establishing a “sugar platform” using the enzyme hydrolysis route under development by NREL and others is most promising.

The risk is reduced by operating an intermediate sized plant continuously to validate the design. The validation costs are high--\$40 to \$50 million—requiring industry partners with financial and technical resources to move ahead even if future government funding and technical support declines.

Developing a process that provides fermentation sugars for production of fuel ethanol and other chemicals expands commercialization interest to include the chemical industry. Their participation brings along additional technical and financial resources that can strengthen the effort.

## **8. RECOMMENDATIONS FOR GOVERNMENT ACTIONS**

Participants look for Government actions to help reduce the risks associated with building the first plant. The major areas for assistance are:

- Process development--continuing to integrate the process, providing additional understanding at a fundamental and macro level
- Sustainable feedstock collection—going beyond erosion control and carbon sequestration in the soil
- Process validation--funding multiple process validation efforts via RFP's

NREL is scheduling a January, 2002 meeting with colloquy participants and others interested to better frame the RFP contents. In addition, Letters of Interest from should be requested interested parties describing how they would like to partner with others and the government to accomplish this. Other recommendations include the following:

### Process development

The National Laboratories, particularly NREL, should continue process development with a focus on corn stover. These activities are best directed by industry to commercialize the results. Partnering with industry is needed, and NREL can pass through intellectual property to their industrial partners.

### Sustainable feedstock collection

Feedstock sustainability issues require better resolution. Previous studies of crop residue removal need to be revised and include other factors in addition to soil erosion and carbon sequestration.

### Process Validation

Participants suggested multiple RFPs should be funded for process validation after framing the contents with industry participation. While no consensus is expected, solicitation of industry's interest can produce better results.

Coordination of RFPs within Energy Efficiency and Renewable Energy Offices and with other Departments is desired. The objective and goals for the RFP should be clearly stated. Supporting information should be included that comprehensively covers the current process technology base. Allow adequate time to respond. Organization of the effort needs to be flexible.

The selection criteria should be set to help insure partners have the necessary resources to complete the work. It should be clear that funding over multiple years may not be available. Since Congress fixes the Federal budget on an annual basis there is no assurance DOE funding will be adequate in future years to support the projects.

Selection should also be based on the ability to clearly extend the outcome to a large market segment without much additional work. For example, one criterion could be that the feedstock selected along with the pretreatment process, hydrolysis to sugars will be adequate to supply 5 % or more of the transportation fuel market along with meeting the needs of chemical and polymer producers for relatively consistent and pure fermentation sugars.

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